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Document de référence 2004/04

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Reference Document 2004/04

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Determination of Discards of Georges Bank Cod from Species Composition Comparison

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ABSTRACT

Despite use of a variety of techniques, including gear modification and alteration of fishing locations, to achieve an appropriate species mix in the catch, unreported discarding of cod in the traditional groundfish fisheries on Georges Bank may occur. Comparison of species composition (ratio of cod to haddock plus pollock) between unobserved landings and landings from trips where an observer was on board was used to detect discarding and to determine the total catch of cod. Factors that are expected to affect the species composition include fishing ground location, season and fleet. The species composition showed great variability, but persistent effects for zone, quarter and fleet were detected. The landings multiplier, defined as the ratio of the observed species composition to the unobserved species composition, is the factor needed to multiply the unobserved landings by in order to obtain their total catch of cod. While the species composition was affected by location, season and fleet, the landings multiplier, which reflects discarding practices, did not show persistent patterns for location and season. Accordingly, annual fleet specific multipliers for longliners and otter trawlers less than 65 feet were derived using an ANOVA on ln species composition and assuming a multiplicative process. The landings multipliers for longliners fluctuated around one; therefore discarding could not be detected. The landings multipliers for otter trawlers were about 1.5 for 1997, 1998 and 1999, suggesting that substantial discarding had occurred in those years, but has fluctuated around one since 2000.

RÉSUMÉ

Malgré le recours à diverses techniques, dont des modifications aux engins et des changements de lieux de pêche, en vue d'obtenir un mélange d'espèces souhaitable dans les prises, il se peut qu'il y ait des rejets non déclarés de morue dans les pêches traditionnelles de poisson de fond sur le banc Georges. Une comparaison de la composition des prises par espèce (proportion de morue par rapport à l'aiglefin plus la goberge) entre les débarquements provenant de sorties qui n'ont pas fait été assujetties à observation et ceux qui provenaient de sorties durant lesquelles un observateur était présent a bord du bateau a servi à détecter les rejets et à déterminer les prises totales de morue. Parmi les facteurs qui devraient influer sur la composition des prises, il faut citer les lieux, la saison et la flottille de pêche. La composition des prises s'est révélée très variable, mais elle présentait des effets constants en fonction de la zone, du trimestre et de la flottille. Le multiplicateur des débarquements, défini comme étant la proportion de la composition des prises assujetties à observation par rapport à la composition des prises qui ne faisaient pas l'objet d'une vérification par un observateur, est le facteur dont on a besoin pour multiplier les débarquements qui n'ont pas été vérifiés par un observateurs pour obtenir les prises totales de morue. Bien que la composition des prises subissait l'influence du lieu, de la saison et de la flottille, le multiplicateur des débarquements, qui reflète la pratique de rejets, ne présentait pas de tendance constante en fonction du lieu et de la saison. Par conséquent, des multiplicateurs annuels propres les uns à la flottille de palangriers et les autres à la flottille de chalutiers de moins de 65 pieds pêchant au chalut à panneaux ont été calculés d'après une analyse de variance de la composition des prises selon l'espèce et un processus multiplicatif hypothétique. Les multiplicateurs des débarquements dans le cas des palangriers fluctuaient alentour de un; par conséquent, on n'a pu déceler de rejets. Pour ce qui est de la flottille de pêche au chalut à panneaux, les multiplicateurs étaient d'environ 1,5 pour 1997, 1998 et 1999 - ce qui laisse croire que d'importants rejets ont eu lieu dans les années en question - mais il a fluctué alentour de un depuis 2000.

INTRODUCTION

The traditional Canadian groundfish fishery on Georges Bank catches primarily cod, haddock and pollock with smaller amounts of white hake and cusk. Since the mid 1990s, a fishery for yellowtail flounder has developed where small amounts of the traditional groundfish are caught. Catch quotas are a principal feature of Canadian fisheries management and achieving catches that match multiple quotas can be difficult. The Canadian quota for cod was reduced substantially in 1995 and has remained low while the quota for haddock has been increasing. Fishermen have used a variety of techniques, including gear modification and alteration of fishing locations, to achieve an appropriate species mix in their catch. Nonetheless, there have been allusions to discarding of cod in the traditional groundfish fisheries.

With few exceptions, trips with observers, fishing trips can be entirely on Georges Bank or entirely outside of Georges Bank, but they cannot be mixed. All groundfish trips to Georges Bank are subject to dockside monitoring an independent contracted party. These companies are responsible for recording the weight that is landed by species and collecting the log books that fishermen are required to complete for each trip. The log books are used to pro-rate the total weight to the individual fishing events during the trip, thereby attributing the catch to location and date/time of capture. The landings data are considered reliable. Operations at sea are subject to a variable amount of observation, also by an independent contracted party, averaging overall for Georges Bank, about 10% coverage of landed weight. Discarding of groundfish is not permitted. Accordingly, discarding does not occur on observed trips. The possibility exists that discarding may occur on unobserved trips. The purpose of this paper is to evaluate data for evidence of discarding and to determine the total catch of cod, including discards, by comparing the species composition by weight between unobserved landings data and landings data from trips where an observer was on board.

DATA

Data from the DFO fisheries statistics database for 1995-2002 were examined. Factors that are expected to affect the species composition include fishing ground location, season and fishing fleet. Quarters were used to stratify season. The definition of zones and fishing fleets aimed to identify strata within which fishing outcomes were relatively homogeneous.

Zones were defined for Georges Bank based on areas of fishing concentration and homogeneity of species composition (Fig. 1). While there appears to be considerable local scale variation in species composition, the zones could not be made too small given the low observer sampling intensity. Fishing operations tend to differ when pollock is sought. Within Zone A, fishing events that sought pollock, identified as those where the catch of pollock exceeded the catch of cod and haddock, were treated separately.

A fishing fleet was defined by gear, tonnage class and participation in the Temporary Vessel Replacement Program (TVRP is a mechanism by which a sector can contract another sector to catch their quota without transferring the quota). For longline and gillnet gear, tonnage class is not thought to affect fishing practices in a manner that would impact species composition. Further, the vessels using longline gear only participated in the TVRP program for a few trips in some years and vessels using gillnet gear did not participate at all. Therefore, tonnage class and TVRP were not used to further partition the longline and gillnet fishing fleets. For otter trawl gear however, vessels of different sizes operate under separate plans and may fish differently. Also, vessels participating in the TVRP may alter fishing practices. Accordingly, seven fleets were identified for otter trawl, tonnage classes 1&2, tonnage classes 1&2/TVRP, tonnage class 3, tonnage class 3/TVRP, tonnage class 4, tonnage class 4/TVRP and tonnage class 5.

Fishermen indicated that small catch quantities of a species may not get recorded for each fishing event on a logbook. Rather, those catches may be aggregated and attributed to the largest catch of that species for the day. Initial exploration revealed a disparity in the frequency of small catches recorded in the logbooks compared to the observer records. To reduce the high variability associated with small catches, catches from all fishing events from a trip within each zone were aggregated. Therefore the basic record unit was the aggregate of catches from a trip within each zone, referred to as a sub-trip. A few sub-trips remained where either the catch of cod or the catch of haddock plus pollock were zero. This was likely due to either aborted trips or to brief forays into a zone. These records were removed from further analysis.

The aggregate catch of cod, haddock and pollock from traditional groundfish trips is generally of the order of a few to tens of tons. By partitioning trips into sub-trips, brief forays into a zone may result in small catches of cod, haddock and pollock. Investigation of running averages of the ratio of cod to haddock plus pollock on sub-trips ordered from smallest catch to largest revealed that the ratio was rather erratic when the aggregate catch was less than 1t. Accordingly, all sub-trip records where the aggregate catch of cod, haddock and pollock was less than 1t were removed.

DATA EXPLORATION

Catch of the prominent groundfish species, cod, haddock, pollock, yellowtail flounder, white hake and cusk, were displayed by zone and quarter using pie charts for landings from unobserved and observed sub-trips (Fig. 2). The highest quantities and the highest proportion of cod are caught in the cod-haddock fisheries in zones A and B. The percentage of cod caught in the pollock fishery in zone A was substantially lower. Zone D contains the fishing grounds for the yellowtail flounder directed fishery and few cod are caught there. Zone C can sometimes be dominated by yellowtail but is generally a haddock fishing ground with some cod. Very little fishing occurs in zone E. Visual inspection of the pie charts revealed some discrepancies between landings from unobserved and observed catch with respect to the proportion of cod, warranting further investigation. Of particular note, the portion of the pie representing cod is almost always larger for the respective observed trips by the OTB TC1-2 and TC3 fleets during 1997, 1998 and 1999. In subsequent years, the portion representing cod varied with respect to whether it was higher on observed or unobserved trips and was generally of similar magnitude. For longline, there was no consistent pattern with respect to the size of the pie for observed or unobserved trips. Comparisons for other fleets were too limited to draw conclusions.

The quantities of white hake and cusk caught on Georges Bank were sporadic and variable. Accordingly it was determined to use the ratio of the catch of cod to the catch of haddock and pollock for all further investigation. Box and whisker plots of cod to haddock and pollock ratios, comparing landings from unobserved and observed catch by fleet, quarter and zones, provide a qualitative sense of the variability in the data and of the patterns in the ratio (Fig. 3). These inspections reinforced the perception of discrepancies in species composition noted with the pie charts. Specifically, the ratio of cod to haddock plus pollock was generally higher for observed trips by OTB TC1-2 and TC3 during 1997, 1998 and 1999. However, the box and whisker plots revealed the great degree of variability in the species composition observations, suggesting that discrepancies would have to be large to be deemed significant and meaningful.

The data exploration led to the following conclusions:

- Species composition is very variable
- Almost all is cod caught in Zones A & B
- Not much cod is caught in the OTB pollock fishery or by OTB >65 feet
- Observer coverage is generally high for OTB >65 feet
- Not enough observer coverage of GN to make comparisons

- 1995 observer coverage is not adequate or representative

Accordingly, further analysis was only pursued for OTB <65 feet and LL in Zones A & B in years 1996-2002. The amount of cod landed from the other zones and by other fleets was relatively insignificant, therefore the absolute amount of discard from these zones would be inconsequential.

DATA ANALYSIS

Define the parameter *m* as,

$$\frac{C_c}{C_o} \Big/ \frac{L_c}{L_o} = m ,$$

where C_c is the observed catch of cod, C_o is the observed catch of haddock plus pollock, L_c is the unobserved landings of cod and L_o is the unobserved landings of haddock plus pollock. Assuming that haddock and pollock are not discarded, since those quotas are not considered limiting, the observed catch of haddock plus pollock is equal to the unobserved landings of haddock plus pollock.

$$C_o = L_o$$

Simplifying shows that the weight of cod caught may be derived from the amount of cod landed if the parameter *m* is known,

$$C_c = mL_c .$$

We require an estimate of the parameter *m*, referred to hereafter as the landings multiplier.

The data from each year and for each fleet was initially analyzed separately to derive an estimator of the landings multiplier. The other factors, zone and quarter, which may influence the ratio of cod to haddock plus pollock, must be accounted for. A multiplicative process is intuitively more appealing for modeling the ratio of cod to haddock plus pollock. Consider two zones and two quarters. Say the ratios for the first and second zone in one quarter were 0.1 and 0.2 respectively. If the ratio for the first zone in the other quarter was 0.4, it seems more natural to expect the ratio in the second zone to be 0.8 rather than 0.5, a multiplicative rather than an additive process. A model with main effects for *source*, i.e. observed catch or unobserved catch, *zone* and *quarter* with appropriate interaction terms could be constructed. Alternatively, since we are not specifically interested in analyzing the effects of *zone* and *quarter*, these can be combined into a composite *zone/quarter* factor. The ensuing model with main effects for *source* and *zone/quarter* with interactions is equivalent but simpler to interpret. Accordingly, consider the multiplicative model

$$Y_{ijk} = \mu\left(source_i^{X_1}\right)\left(zone/quarter_j^{X_2}\right)\left(source_i \otimes zone/quarter_j^{X_3}\right)\varepsilon_{ijk}$$

where Y_{ijk} can be either the $\frac{C_c}{C_o}$ or $\frac{L_c}{L_o}$ associated. The subscripts *i*, *j* and *k* index

source, quarter and trip record respectively. The variables X are simply dummy variables indicating if the ratio corresponds to a source or zone/quarter when the value is 1 and have a

value of 0 otherwise. Taking natural logarithms results in a linear model and stabilizes variance, giving

$$\ln Y_{ijk} = \ln \mu + (\ln source_i X_i) + (\ln zone/quarter_j X_j) + (\ln source_i \otimes zone/quarter_j X_{ij}) + \varepsilon_{ijk}.$$

This is a typical linear model and can be solved using least squares, after imposing one linear constraint for each factor and interaction. Using the constraint ln *source*$_i$ = 0 when *source*$_i$ is the unobserved catch means that the landings multiplier is $\phi_j = e^{\theta_j} = e^{(\ln source_j - \ln source_i \otimes zone/quarter_j)}$ where *source*$_i$ is the observed catch and *source*$_i$ ⊗ *zone/quarter*$_j$ is the interaction term for the relevant *zone/quarter*. If the interaction terms are not significant, the landings multiplier is constant for all *zone/quarter* composites and is obtained as $\phi_j = e^{\theta_j} = e^{(\ln source_i)}$.

Assuming that ε are distributed according to a Gaussian distribution, an unbiased estimator of the landings multiplier is given by

$\hat{\phi}_j = e^{\theta_j} g_v\left[-\frac{v+1}{v}\frac{\hat{\sigma}_\theta^2}{2}\right]$ (Bradu and Mundlak 1970) where v are the degrees of freedom

and $g_v(arg)$ can be approximated by e^{arg} for sufficiently large degrees of freedom (Ebbeler 1973).

An estimate of the variance of the landings multiplier is given by

$e^{2\theta_j}\left\{g_v^2\left[-\frac{v+1}{v}\frac{\hat{\sigma}_\theta^2}{2}\right] - g_v\left[-\frac{v+1}{v}2\hat{\sigma}_\theta^2\right]\right\}$ (Bradu and Mundlak 1970).

As indicated above, only zones A and B were included in the analysis. There was no Canadian fishery in the first quarters of 1996 to 2002. ANOVA results (Tables 1) for OTB TC1&2 non-TVRP in 1998 are fairly typical and indicate that the amount of variance explained by the model is very low but the factor effects are significant nonetheless. Note that the F statistic for the interaction term is considerably smaller and would only be marginally significant or not at all.

The predicted ratio of cod to haddock plus pollock for unobserved trips confirmed the pattern suggested by the exploratory analysis that the ratio is higher in zone B than in zone A (Table 2). While this pattern for the ratio is fairly obvious, the estimates of landings multiplier do not indicate a consistent differential discarding rate in the two zones (Table 3). Similarly, quarter, tonnage class and, most strongly, TVRP appear to affect the ratio of cod to haddock plus pollock but there are no consistent patterns across these factors for the landings multiplier. Investigation of alternative ANOVA models supported this interpretation. While the effect of zone/ quarter/tonnage class/TVRP for OTB and zone/quarter for LL on ratio were significant, their interaction effect with source was much less. The low significance of the interaction terms suggests an absence of a predictable pattern for the landings multiplier across these factors. Accordingly it was determined to retain the main effects composite factors for the ratio but remove the interaction and thereby derive annual fleet landings multipliers.

The annual estimates of the landings multiplier for OTB and LL are shown with bars indicating plus and minus one standard error in Fig. 4. The similarity of the multipliers using the observed and unobserved trips only from vessels which carried an observer in any given year to

the results obtained with all vessels indicates that the observed vessels were representative of the fleet. The landings multipliers for longliners fluctuated around one, therefore discarding could not be detected. The landings multipliers for otter trawlers were about 1.5 for 1997, 1998 and 1999, suggesting that substantial discarding had occurred in those years, but has fluctuated around one since 2000. Rejection of the hypothesis that discarding did not occur in 1996, 2000, 2001 and 2002 is not supported by the data and these analyses. It is noted though that, due to high variability, substantial discrepancy between the observed and unobserved ratios of cod to haddock plus pollock is required to detect discarding. The results suggest that 428 mt, 273 mt and 253 mt were discarded by the OTB fleet during 1997, 1998 and 1999 respectively (Table 4). These discard amounts are substantial relative to the total reported catch of cod from eastern Georges Bank in those years, 3,476 mt, 2,702 mt and 2,968 mt respectively (Hunt et al 2003). The catch at age used for the stock assessment should be revised to reflect these discard amounts but will require investigation of the size composition of the discards to determine how to apportion across ages.

REFERENCES

Bradu, D., and Y. Mundlak. 1970. Estimation in log-normal linear models. J. Am. Statist. Assoc. 65: 198-211.

Ebbeler, D.H. 1973. A note on estimation in log-normal linear models. J. Statist. Comput. Simul. 2: 225-231.

Hunt, J.J., B. Hatt, and L. O'Brien. 2003. Population status of eastern Georges Bank cod (unit areas 5Zj,m) for 1978-2004. CSAS Research Document 2003/096. pp47.

Table 1. Example ANOVA results for a typical case: OTB TC1&2 non-TVRP for 1998.

MULTIPLE R	0.466
MULTIPLE R SQUARED	0.217

ANALYSIS OF VARIANCE

SOURCEOF VARIATION	DF	SUMSOF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	256.50	256.50	
REGRESSION	11	33.05	3.00	4.28
source	1	5.34	5.34	7.61
zone/quart	5	22.22	4.44	6.33
source⊗zone/quart	5	0.88	0.18	0.25
RESIDUALS	170	119.30	0.70	
TOTAL	182	408.80		

REGRESSION COEFFICIENTS

FACTOR	COEFFICIENT	STD. ERROR	NO. OBS.
unobserved, zone A/quarter 2	-1.886	0.148	182
observed	0.390	0.611	26
zone A/quarter 3	0.871	0.268	19
zone A/quarter 4	0.328	0.284	14
zone B/quarter 2	0.815	0.221	27
zone B/quarter 3	0.913	0.190	65
zone B/quarter 4	0.511	0.232	23
observed⊗zone A/quarter 3	-0.296	0.750	5
observed ⊗zone A/quarter 4	0.165	0.884	2
observed ⊗zone B/quarter 2	0.326	1.049	1
observed ⊗zone B/quarter 3	0.227	0.658	15
observed ⊗zone B/quarter 4	0.318	1.052	1

Table 2. Predicted values for unobserved ratio of cod to haddock plus pollock. Shaded cells indicate which zone had a higher ratio when a comparison was possible.

				Zone A			Zone B		
	GEAR	TVRP	TC	Q2	Q3	Q4	Q2	Q3	Q4
1996	OTB	non-TVRP	1&2	0.17	0.24	0.48	0.53	0.48	0.60
			3	0.22	0.27	0.41	0.32	0.32	0.32
		TVRP	1&2						
			3	0.48	0.04		0.11	0.06	
	Longline				1.05	0.60		2.56	1.36
1997	OTB	non-TVRP	1&2	0.41	0.38	0.52	2.29	0.83	0.47
			3	0.81	0.42	0.50	1.64	0.64	0.58
		TVRP	1&2						
			3						
	Longline			3.53	1.36	1.15	5.90	4.32	3.99
1998	OTB	non-TVRP	1&2	0.21	0.50	0.29	0.48	0.53	0.35
			3	0.26	0.28	0.25	0.43	0.38	0.26
		TVRP	1&2					0.25	
			3	0.12	0.05		0.22	0.10	0.10
	Longline			1.40	0.90	0.76	2.22	3.50	1.57
1999	OTB	non-TVRP	1&2	0.26	0.16	0.30	0.41	0.42	0.67
			3	0.21	0.23	0.40	0.26	0.29	0.30
		TVRP	1&2						
			3			0.06			0.04
	Longline			3.62	1.07	0.91	8.25	6.39	4.04
2000	OTB	non-TVRP	1&2		0.04	0.17	0.20	0.25	1.02
			3		0.20	0.37	0.19	0.23	0.68
		TVRP	1&2						
			3		0.06	0.11		0.08	0.14
	Longline			3.25	0.72	0.49	7.36	2.57	2.97
2001	OTB	non-TVRP	1&2		0.14	0.25	0.24	0.21	0.20
			3		0.12	0.23	0.23	0.14	0.24
		TVRP	1&2		0.01		0.07	0.03	0.04
			3		0.03	0.08	0.14	0.04	0.09
	Longline				0.63	0.28		2.10	1.50
2002	OTB	non-TVRP	1&2		0.11	0.10	0.12	0.20	0.35
			3	0.20	0.07	0.14	0.09	0.08	0.22
		TVRP	1&2						
			3		0.02	0.07		0.06	0.06
	Longline				0.46	0.33		2.36	1.41

Table 3. Landings multiplier by fleet, zone and quarter.

more cod in unobserved catch
more cod in observed catch
BOLD multiplier - se >1

				Zone A			Zone B		
	GEAR	TVRP	TC	Q2	Q3	Q4	Q2	Q3	Q4
1996	OTB	non-TVRP	1&2	0.88		0.55	0.79	1.74	0.72
			3	0.81	1.64	2.08	1.25	**1.84**	1.47
		TVRP	1&2						
			3	0.13	0.45		0.63	1.09	
	Longline				0.73	**1.82**		1.20	1.50
1997	OTB	non-TVRP	1&2	0.70	0.74	1.45	1.27	**2.38**	1.39
			3	0.60		1.85	0.76		**1.90**
		TVRP	1&2						
			3						
	Longline			2.03	1.16		0.49	1.02	0.42
1998	OTB	non-TVRP	1&2	1.22	1.00	1.42	1.42	1.80	1.40
			3	0.59	0.93	1.02	**3.73**	1.59	0.83
		TVRP	1&2					1.55	
			3	0.39	2.56	0.39	1.11	1.71	0.76
	Longline			0.43	0.91	0.58			1.14
1999	OTB	non-TVRP	1&2	1.19	1.25		1.88	1.48	
			3	1.10	1.30		1.16	**1.98**	1.08
		TVRP	1&2						
			3			1.30			5.65
	Longline			1.23	**1.69**	0.52	0.46	0.86	0.45
2000	OTB	non-TVRP	1&2		2.09	1.54		0.87	0.26
			3		0.67	0.18	1.33	1.30	0.30
		TVRP	1&2						
			3		0.63	0.34	0.63	2.68	0.80
	Longline			0.13	0.86	0.30	0.56	1.82	
2001	OTB	non-TVRP	1&2		0.50	0.61	1.35	0.70	1.67
			3		0.24	1.67	1.36	0.94	1.17
		TVRP	1&2		**3.33**		**3.24**		
			3		1.17	1.24	1.44	0.68	0.86
	Longline				0.88	**1.92**		1.27	0.90
2002	OTB	non-TVRP	1&2		1.14	0.41	2.60	0.63	
			3	0.13	0.18	1.95	0.64	1.27	0.11
		TVRP	1&2						
			3		1.08			0.43	
	Longline				0.74	0.48			0.90

Table 4. Summary of annual landings multipliers for OTB and LL and estimated discards for 1997, 1998 and 1999. Values of the multiplier that are less than one are due to random variation in spatial heterogeneity and give an indication of the magnitude of the departure from a value of one that is required to be considered meaningful.

	GEAR	UNOBSERVED LANDINGS	MULTIPLIER	± S. E.	DISCARDS
1995	OTB	264			
	Longline	462			
1996	OTB	397	0.68	±0.12	
	Longline	699	1.02	±0.14	
1997	OTB	856	**1.50**	±0.28	**428**
	Longline	1055	1.05	±0.19	
1998	OTB	463	**1.59**	±0.20	**273**
	Longline	748	0.82	±0.25	
1999	OTB	469	**1.54**	±0.24	**253**
	Longline	706	1.29	±0.32	
2000	OTB	375	0.99	±0.16	
	Longline	619	0.91	±0.28	
2001	OTB	521	1.25	±0.19	
	Longline	964	1.31	±0.33	
2002	OTB	357	0.94	±0.19	
	Longline	617	0.77	±0.24	

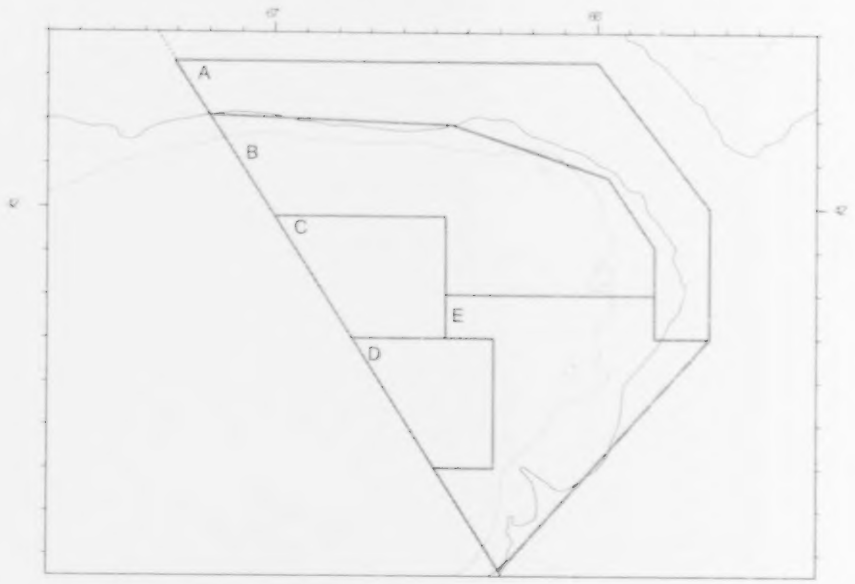


Figure 1. The Canadian portion of Georges Bank was partitioned into five zones that were used for the analysis.

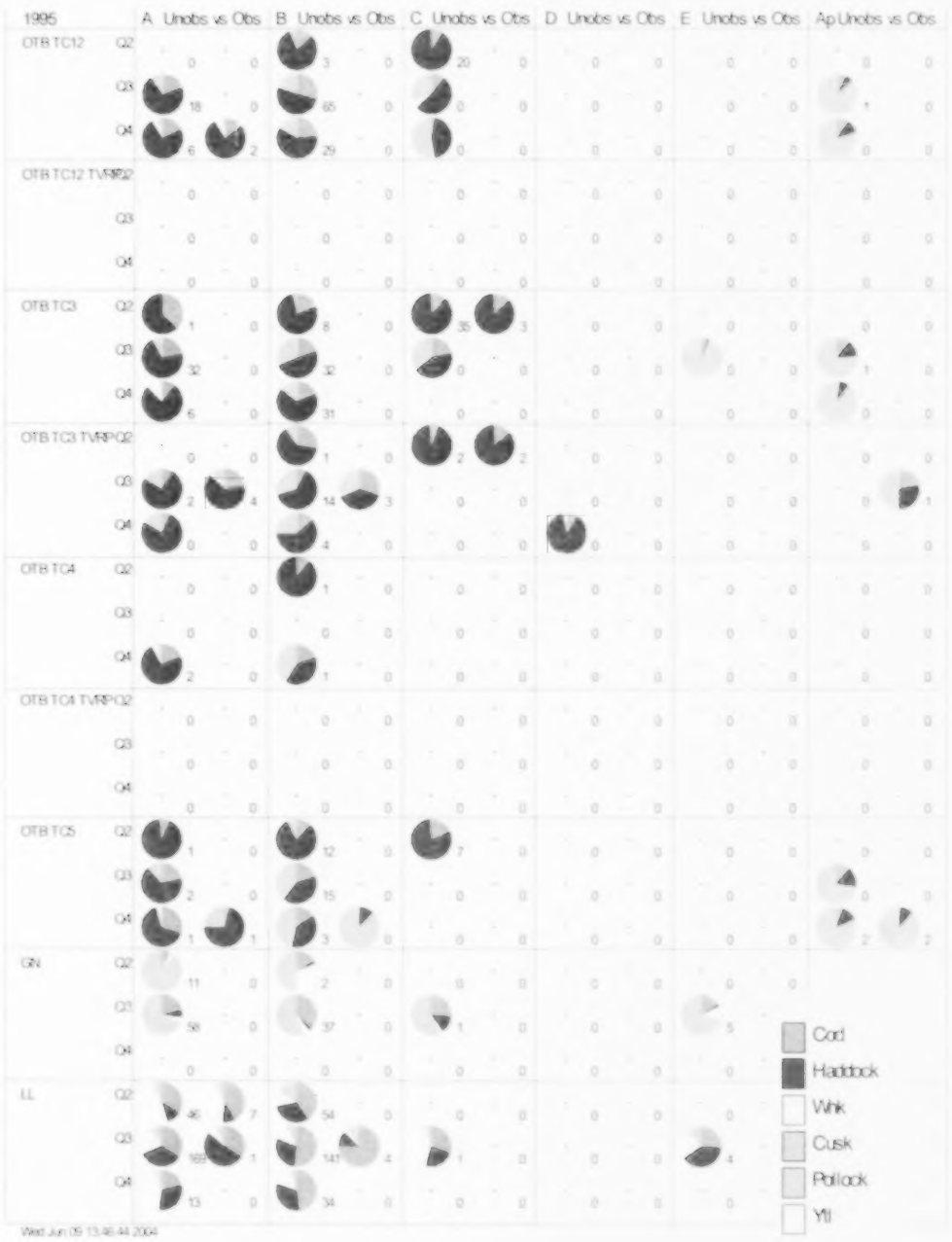
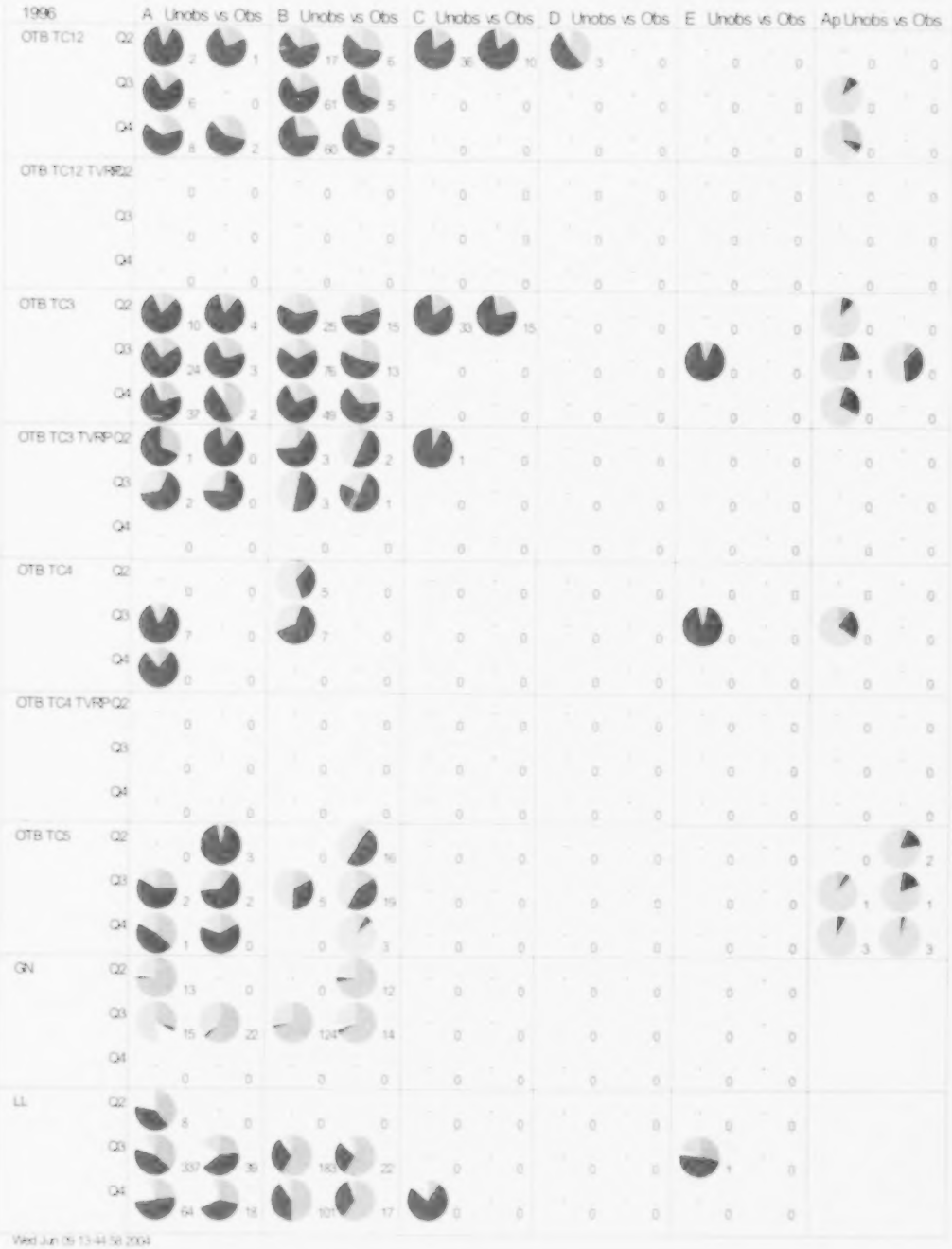


Figure 2. Comparison of species composition for 6 prominent groundfish species from observed (Obs) and unobserved (Unobs) fishing on Georges Bank for otter trawl bottom (OTB), longline (LL) and gillnet (GN) fleets by tonnage class (TC), quarter (Q) and zone (A, B, C, D, E and Ap (> 50% pollock in zone A)). TVRP indicates fishing carried out under the Temporary Vessel Replacement Program. The number next to each pie represents the weight of cod caught in metric tonnes. (The archive of this manuscript retained on the TRAC web site contains a colour reproduction of this figure that may be easier to view.)



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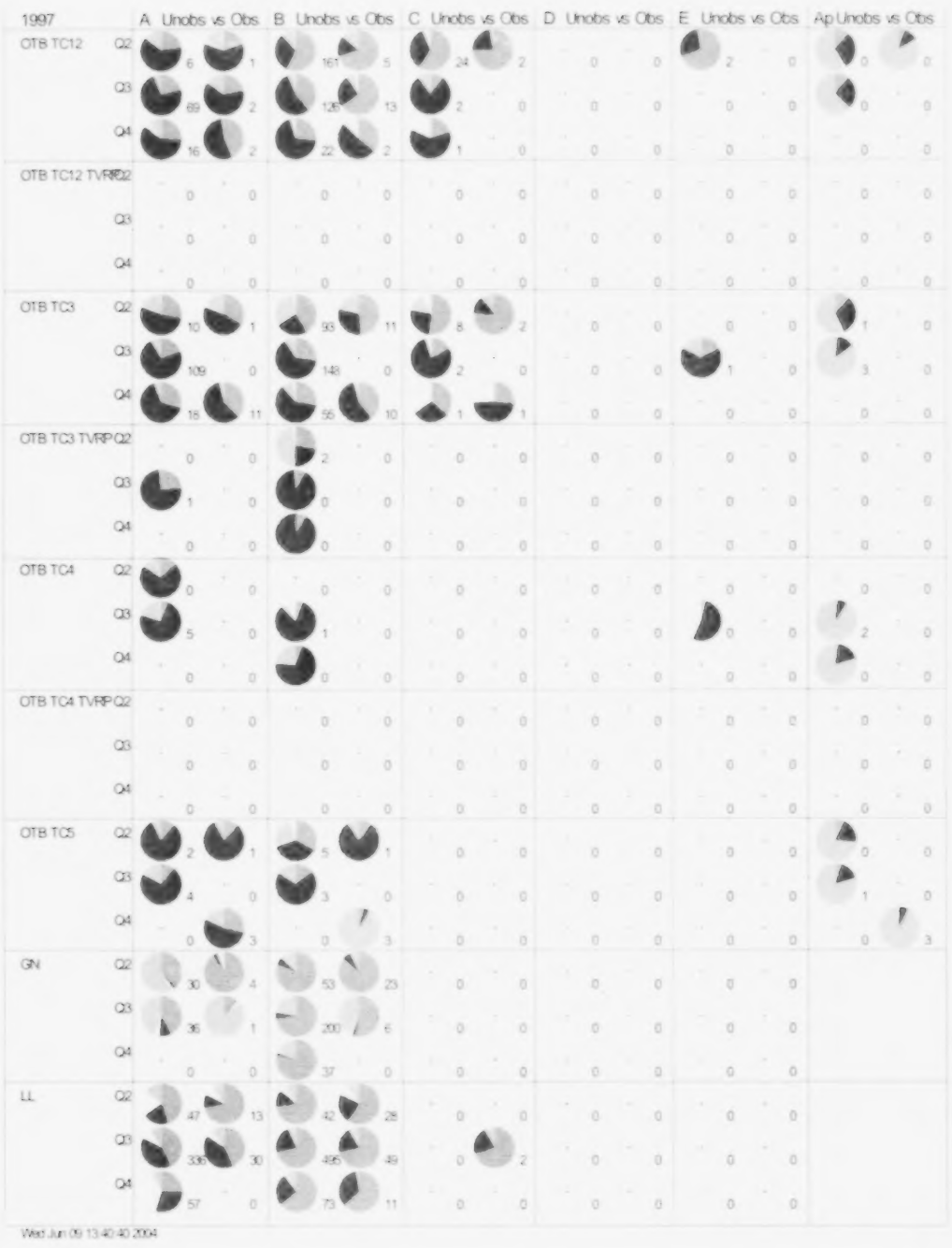

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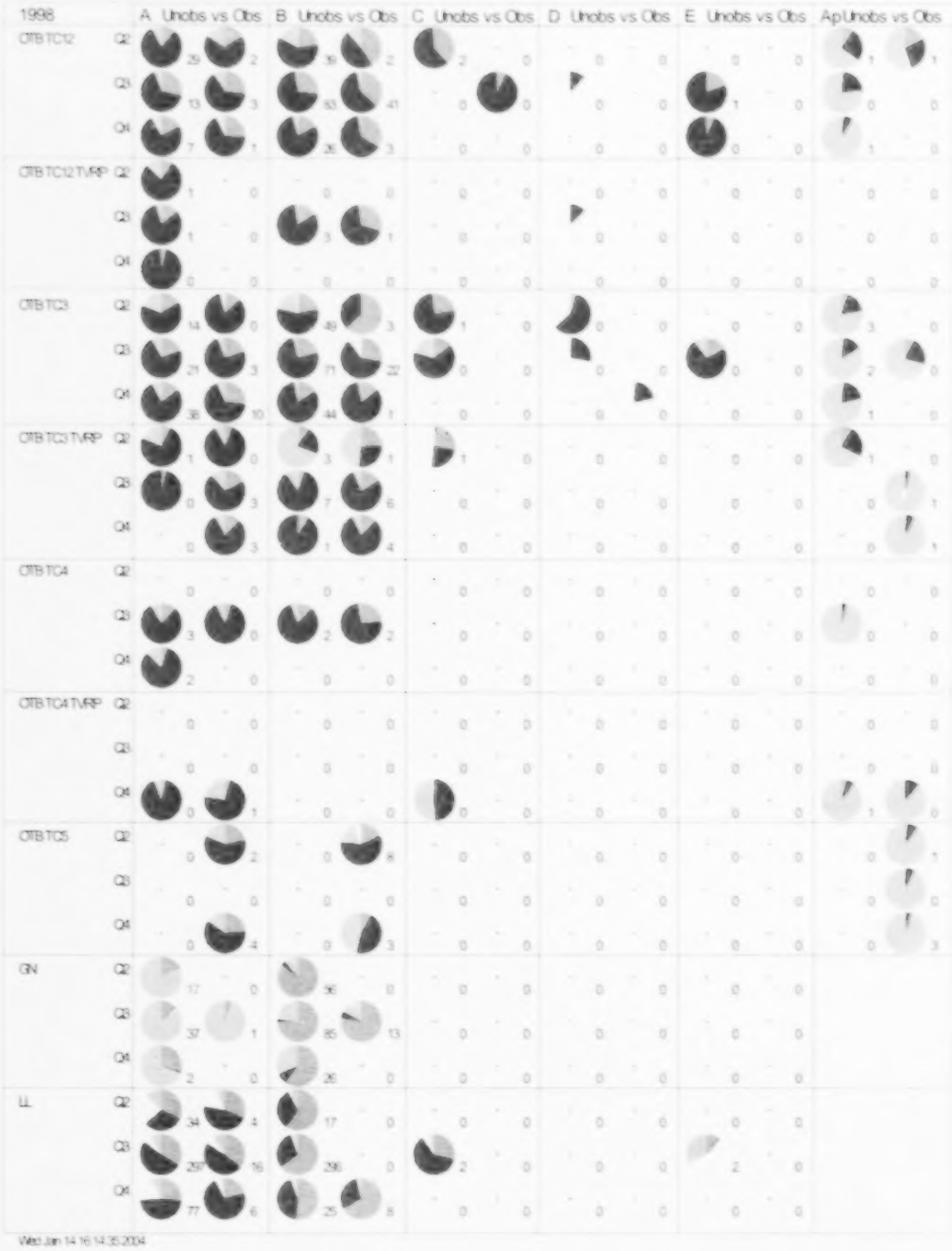

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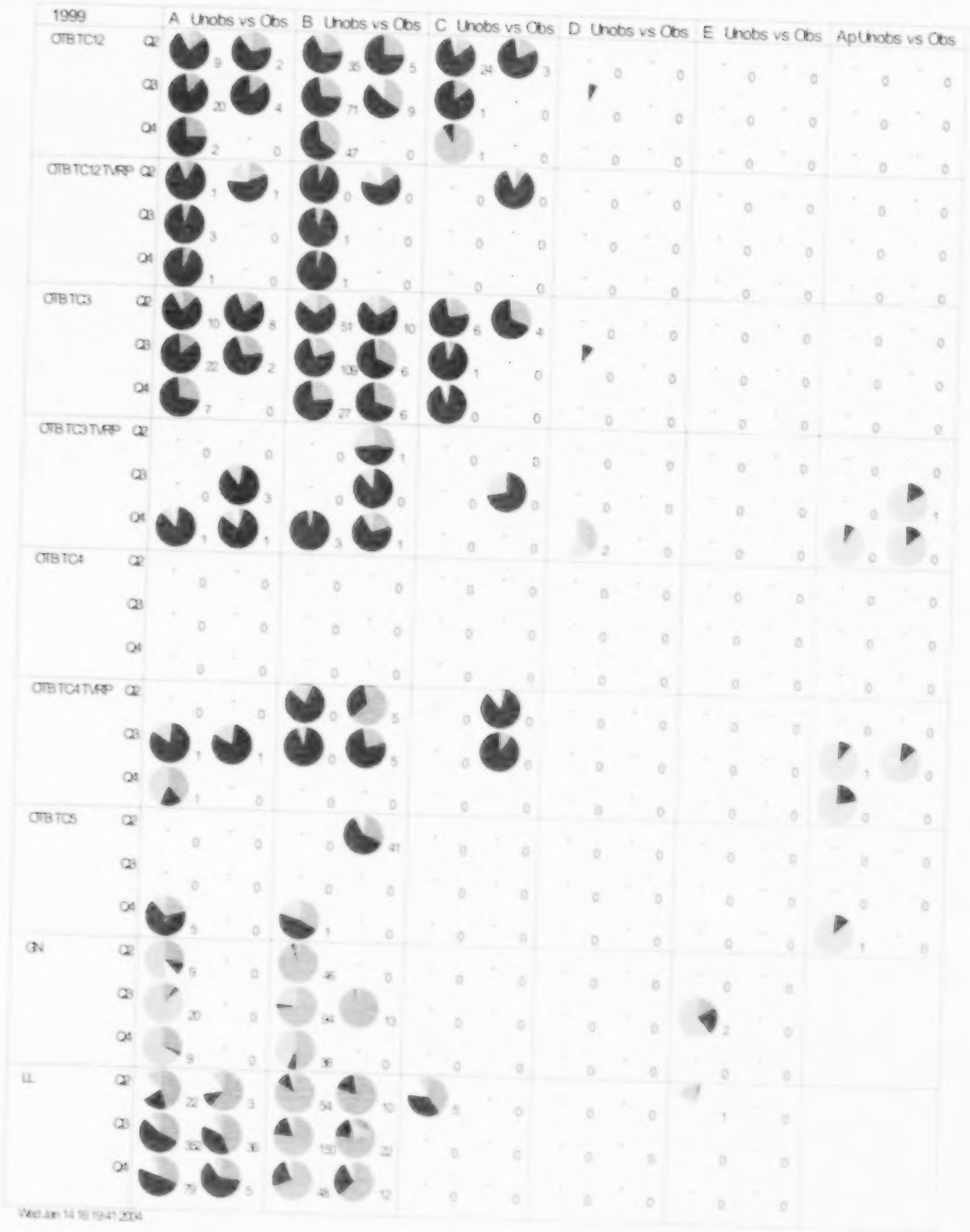

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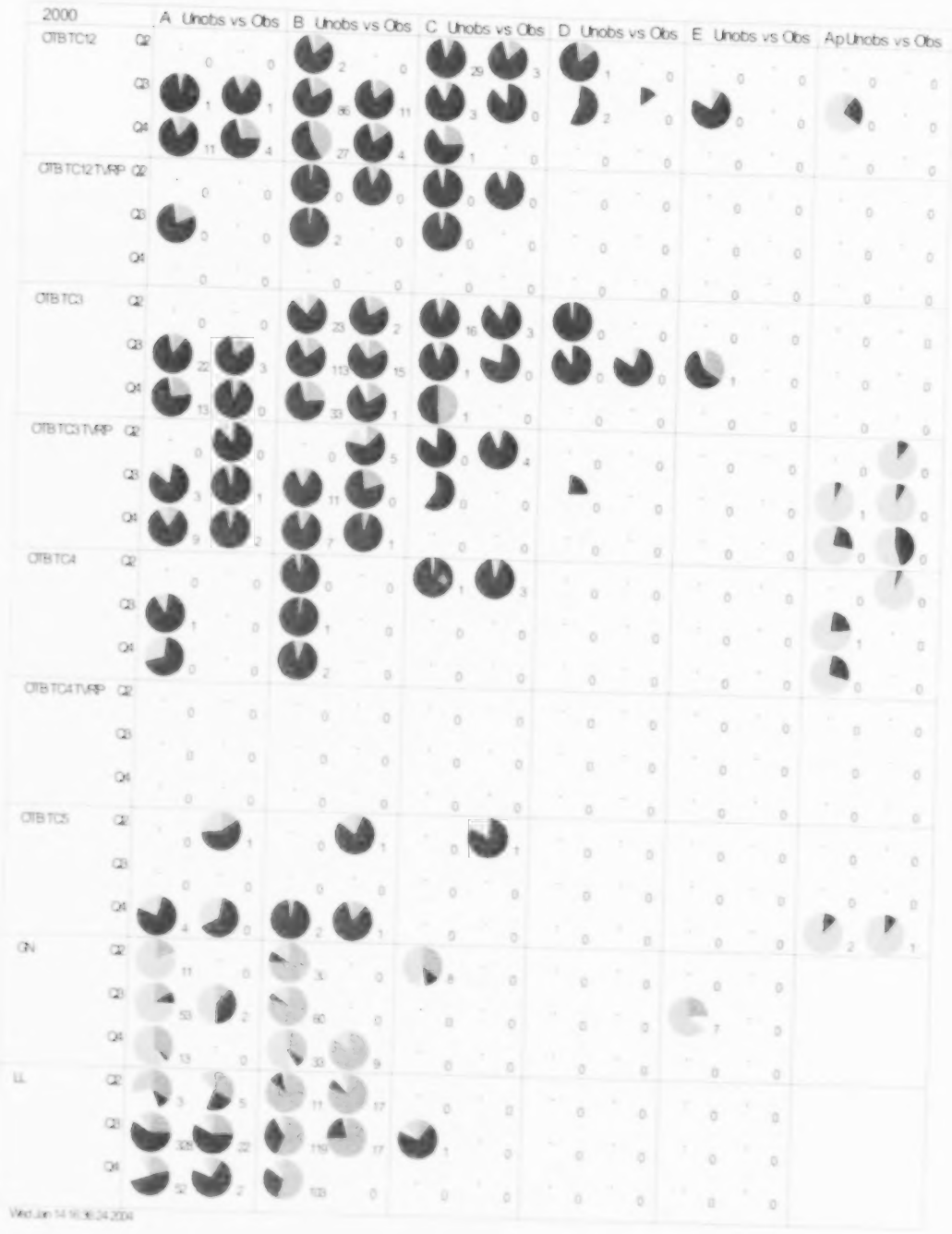

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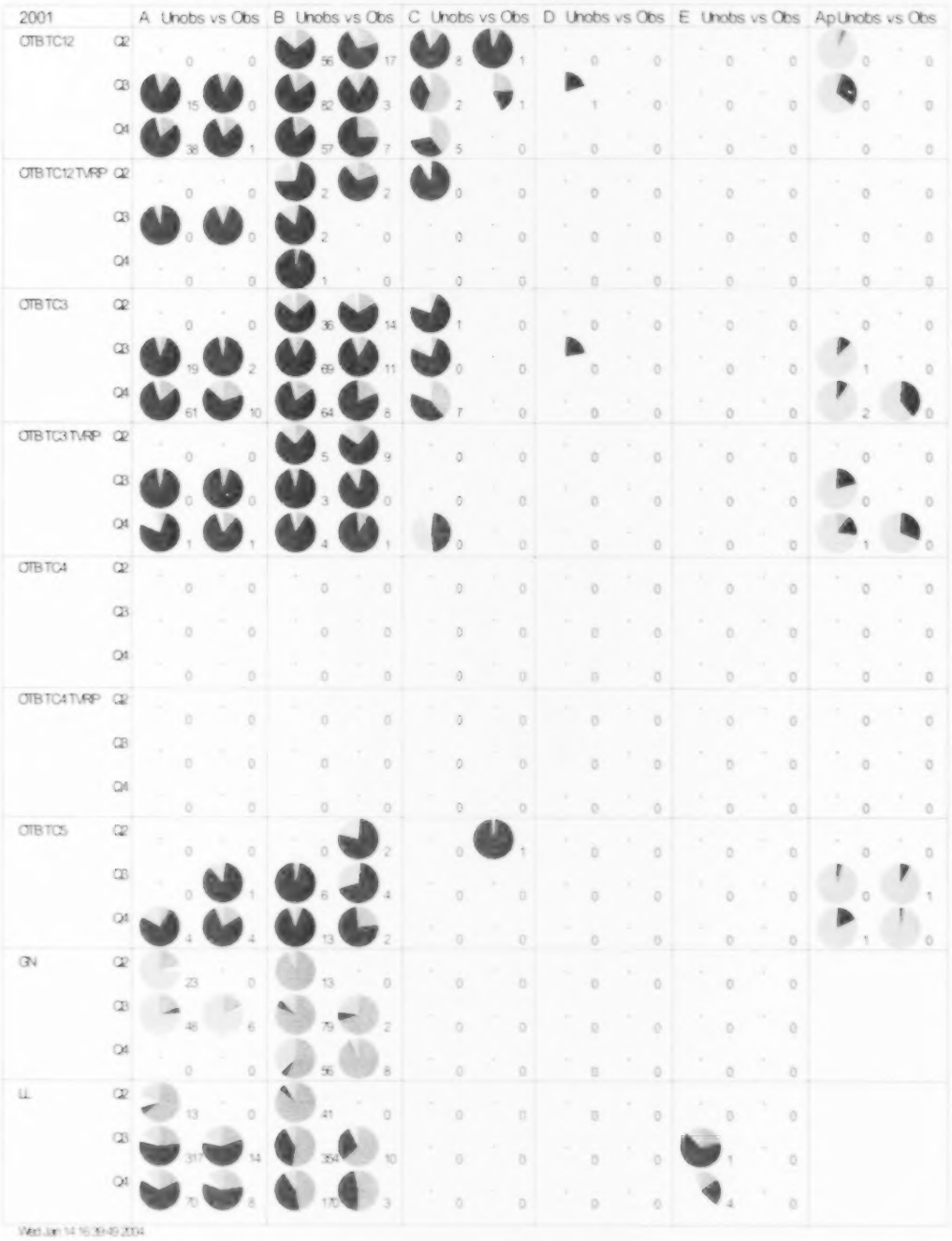

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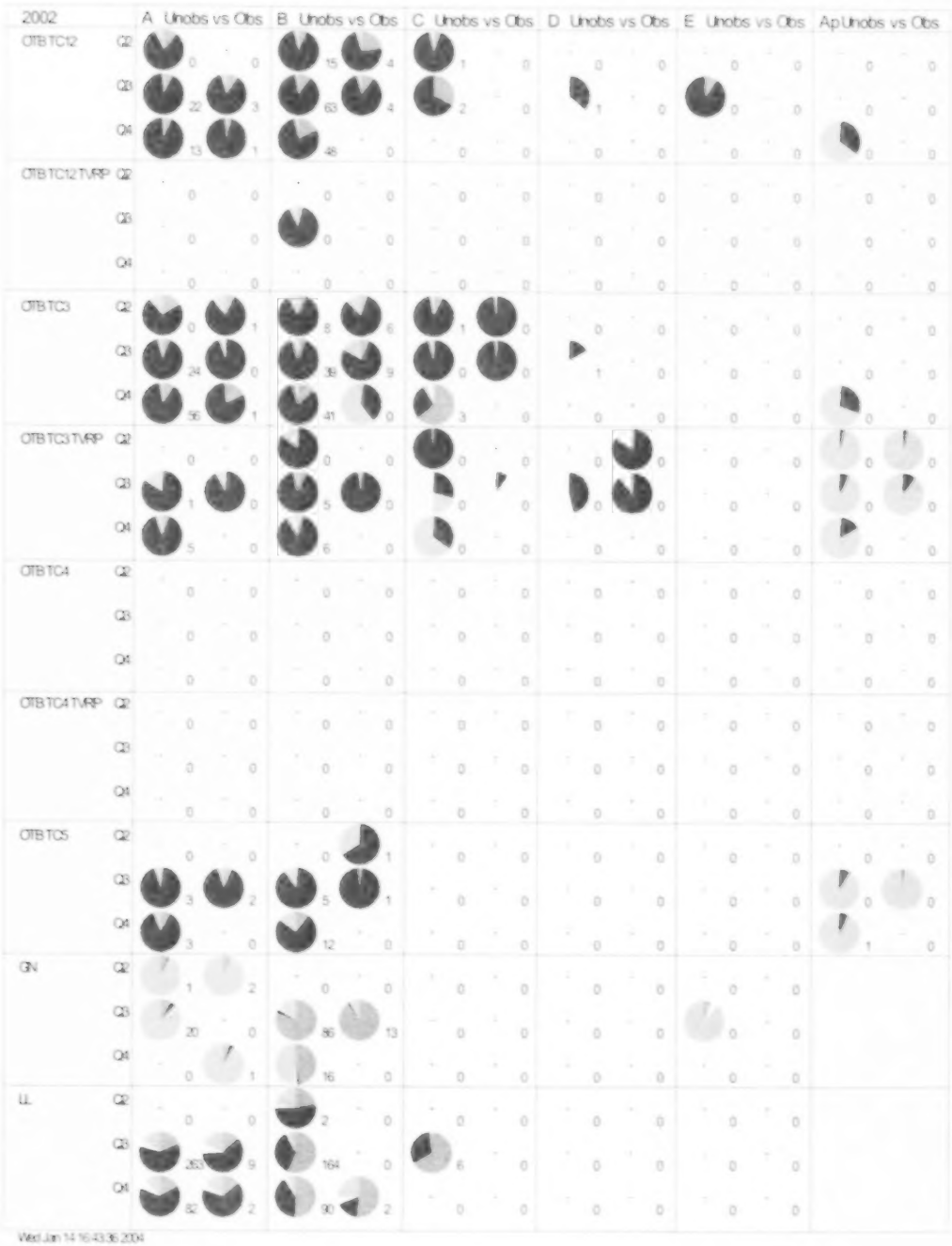

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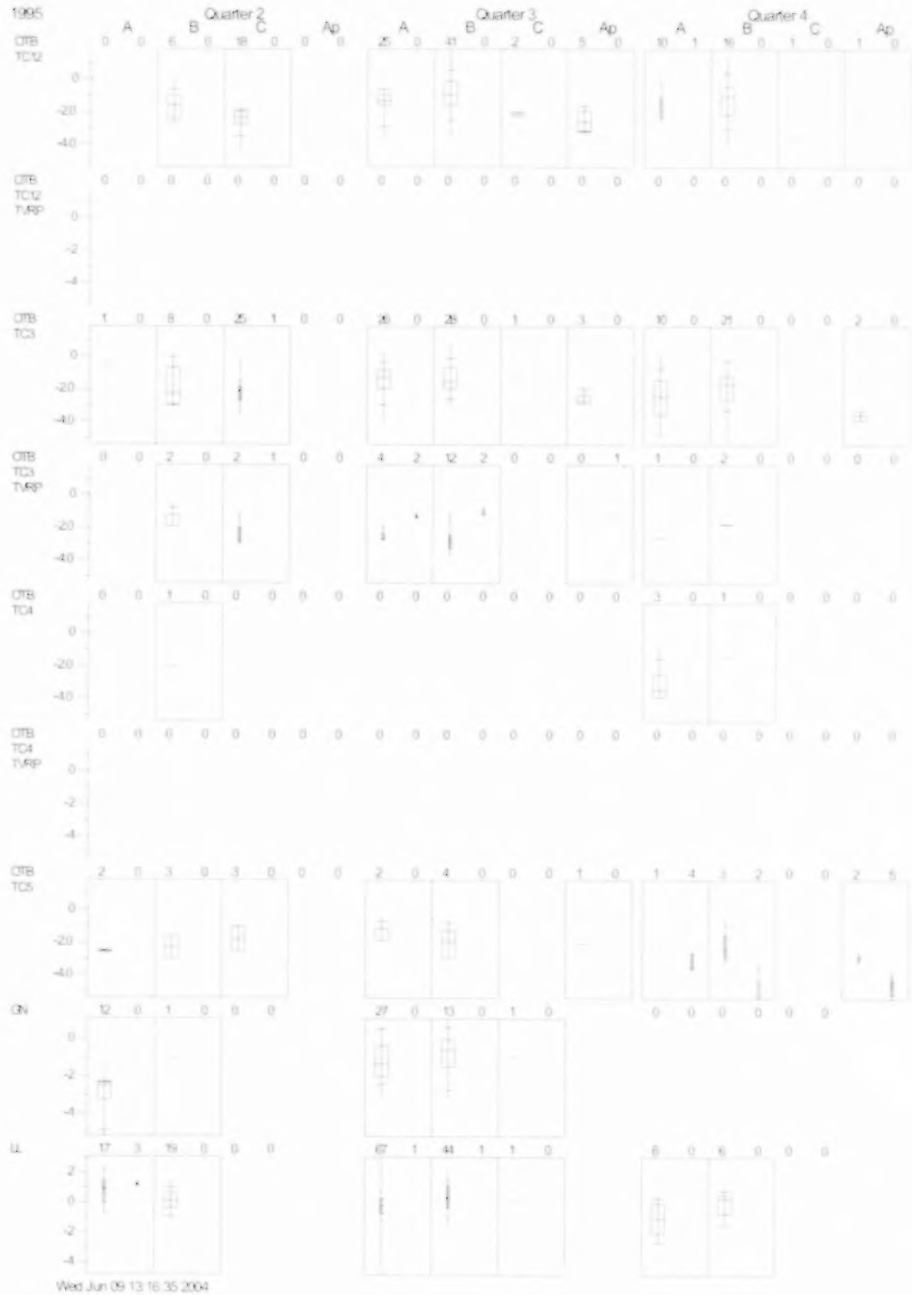
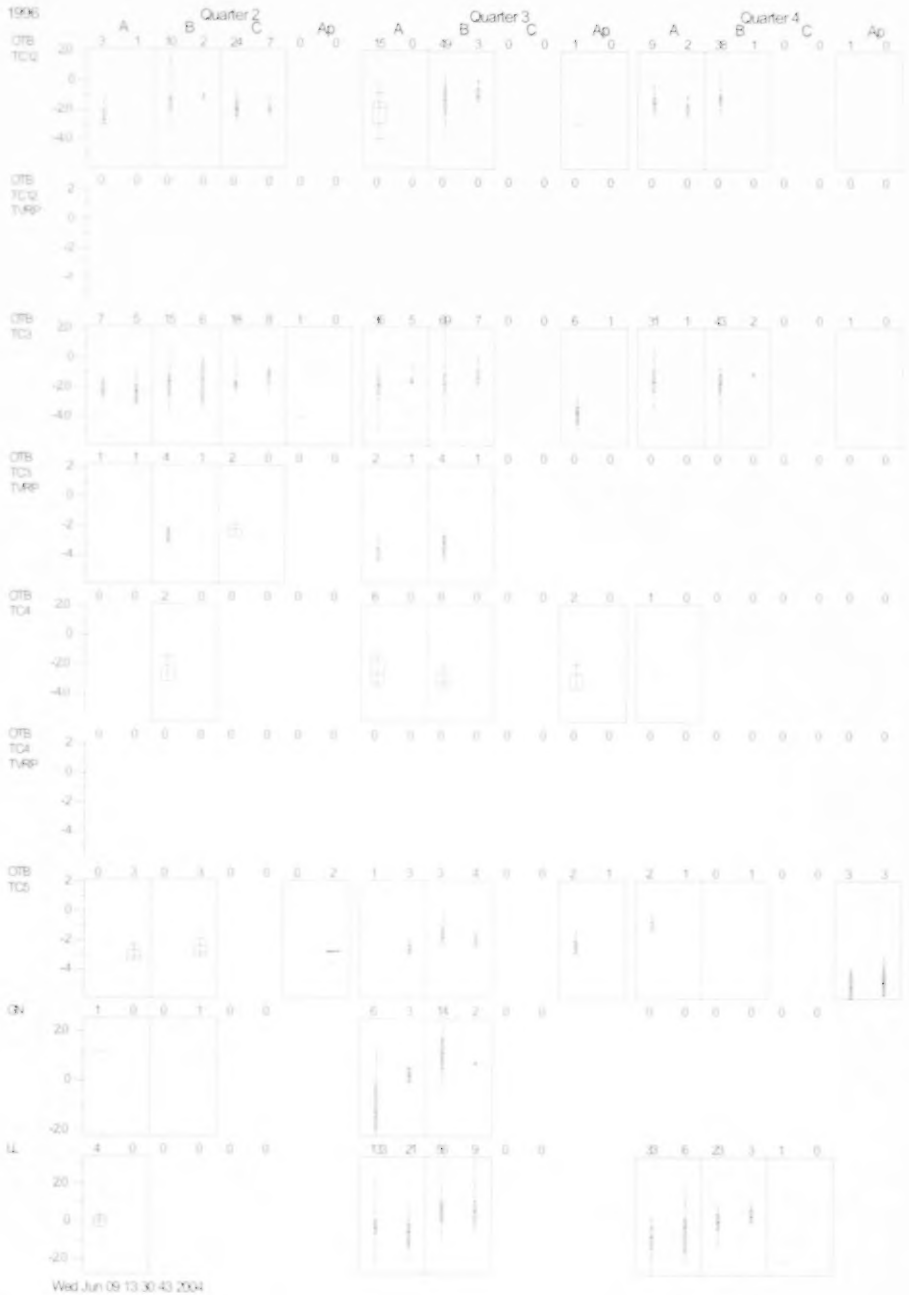


Figure 3. Box whisker plots of *ln* ratio of cod to haddock plus pollock from observed (right) and unobserved (left) fishing on Georges Bank for bottom otter trawl (OTB), longline (LL) and gillnet (GN) fleets by tonnage class (TC), quarter (Q) and zone (A, B, C and Ap (> 50% pollock in zone A)). TVRP indicates fishing carried out under the Temporary Vessel Replacement Program. The number of trips are indicated.



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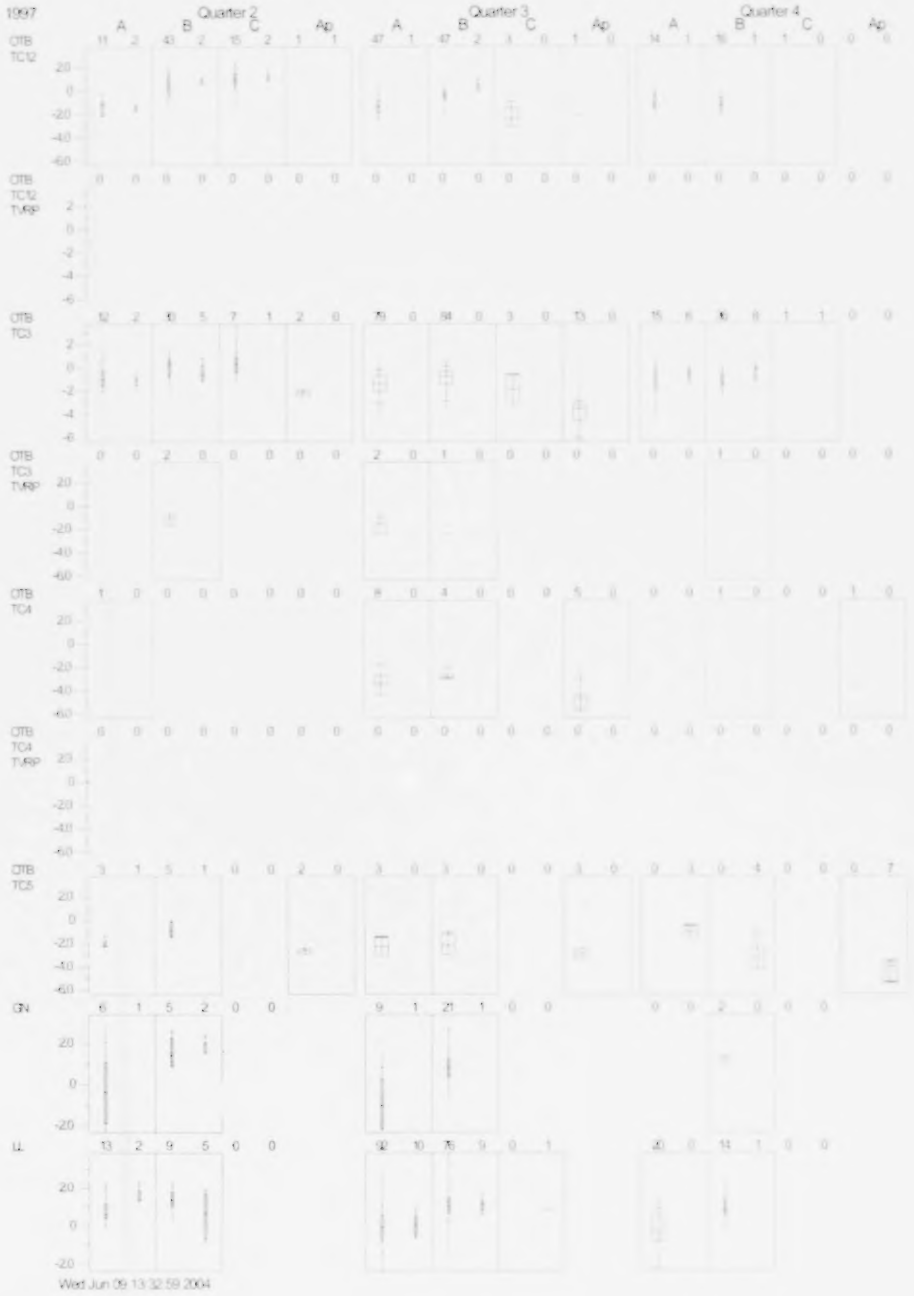

Figure 3. (Continued.)

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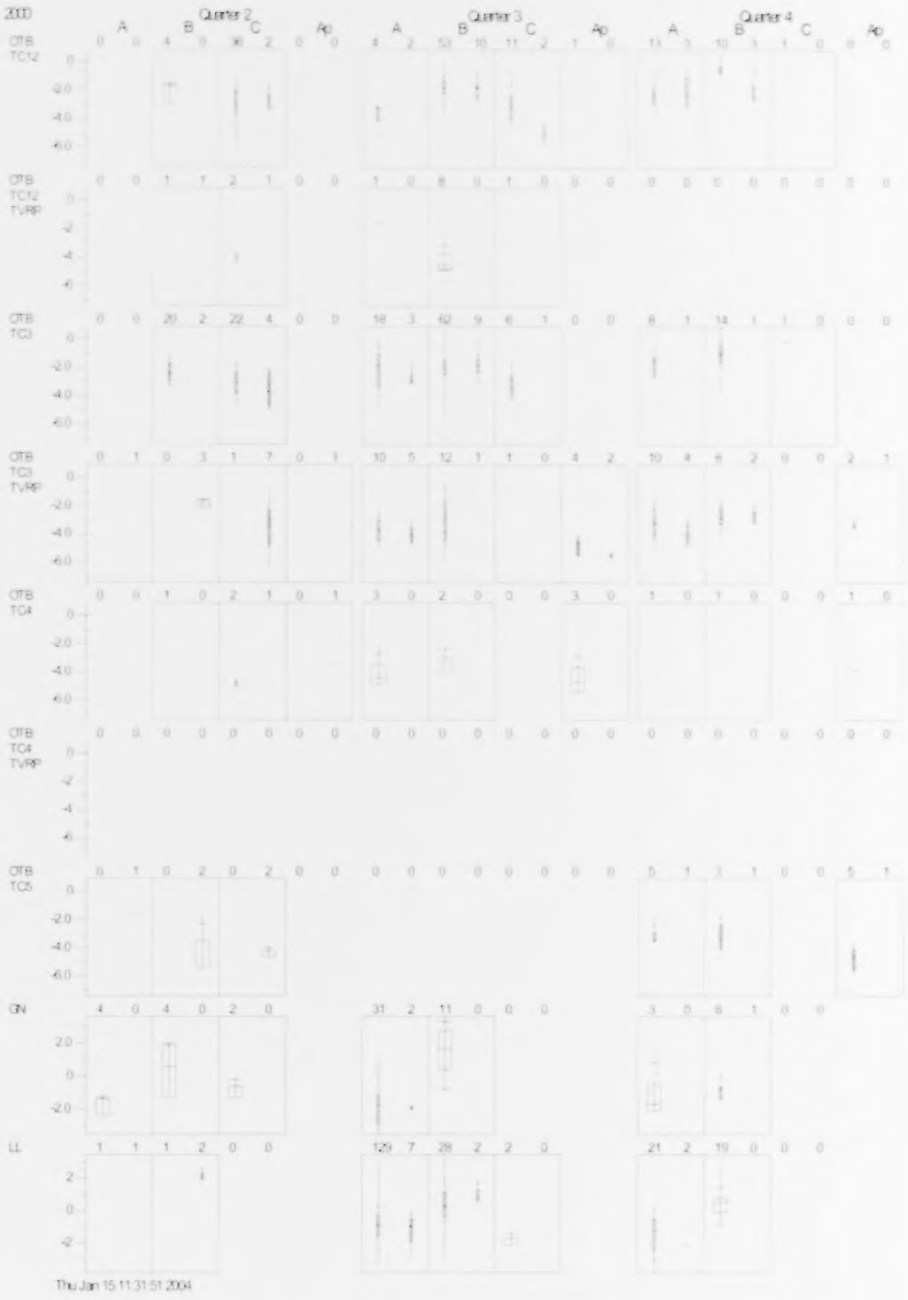

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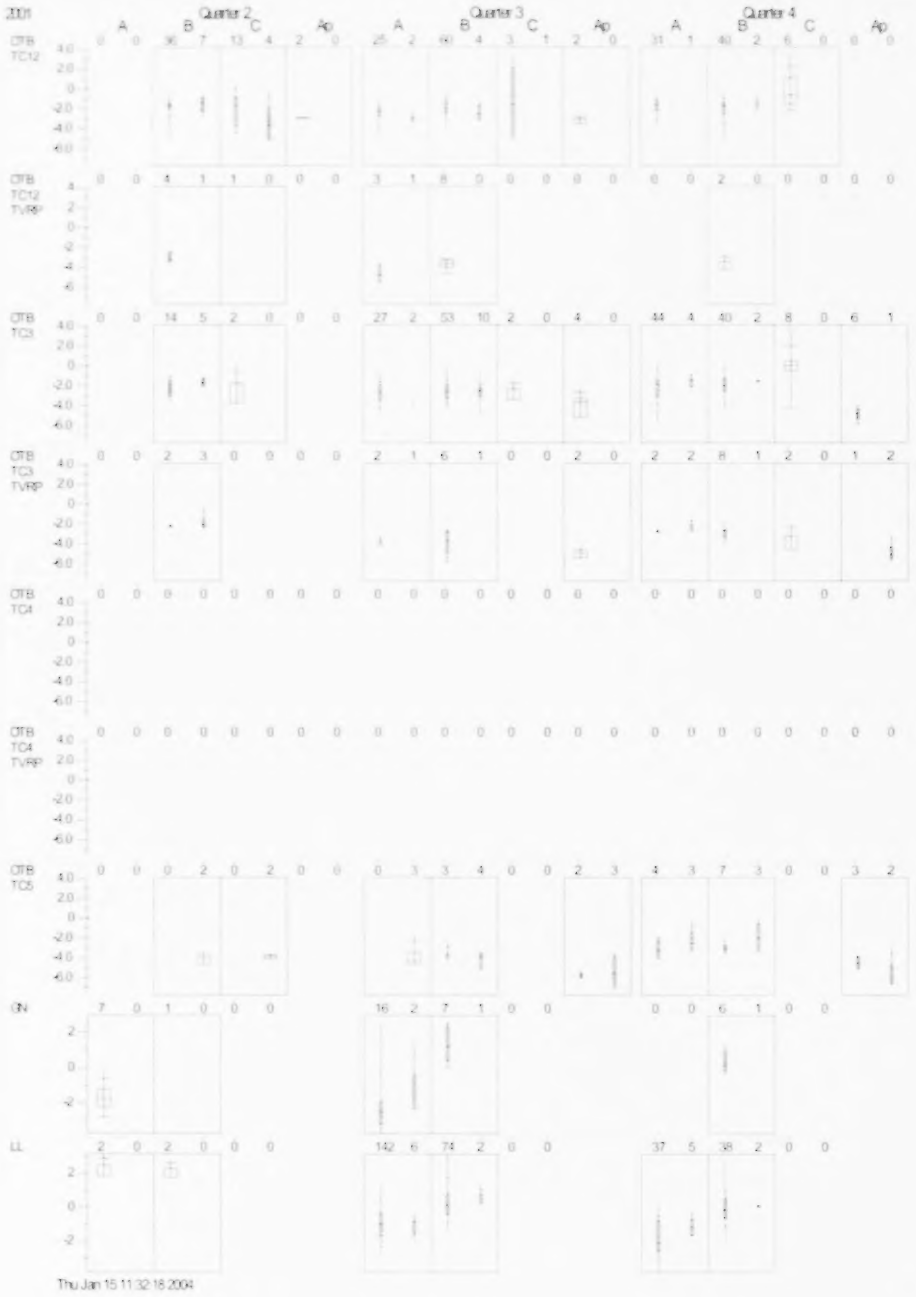

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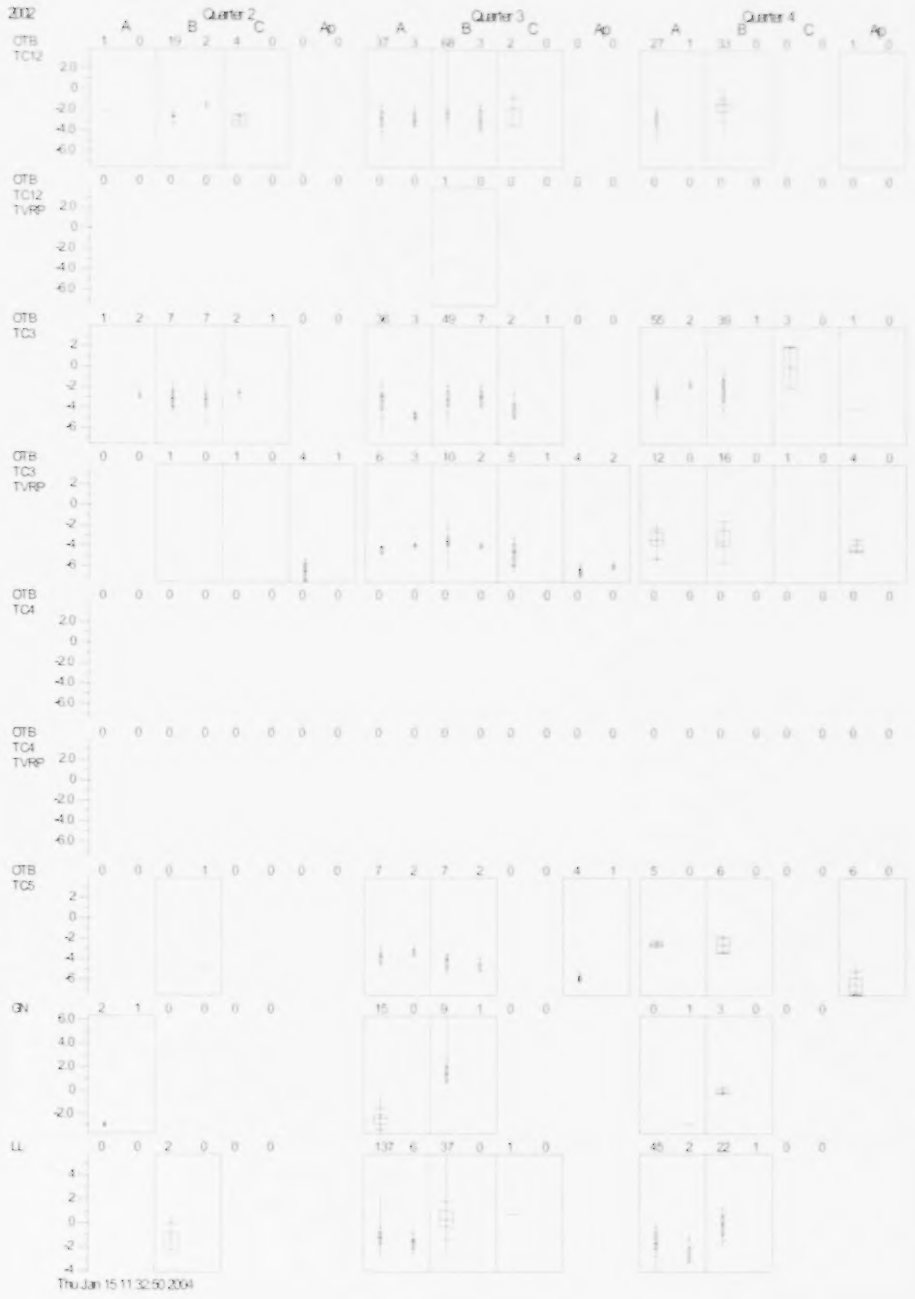

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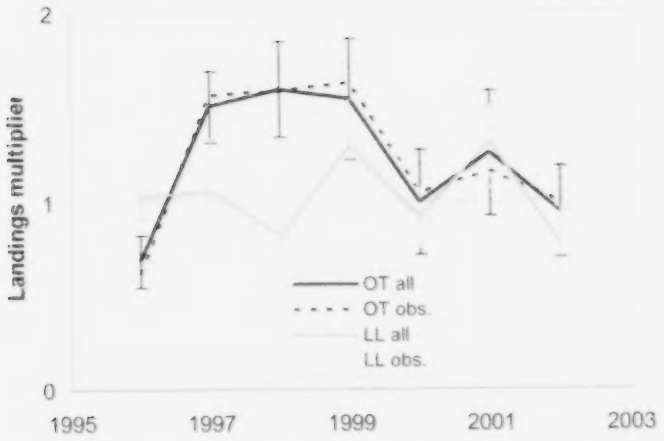

Figure 4. Trend for landings multipliers and comparison with those derived when only observed vessels were included for unobserved data.